Progress Reporting and Review
NASA Kennedy Space Center
Exploration Systems Analysis and Technology Assessment Project

Launch & Landing Effects Ground Operations "LLEGO" Model

Backup Charts ONLY

Including Definitions and Equations

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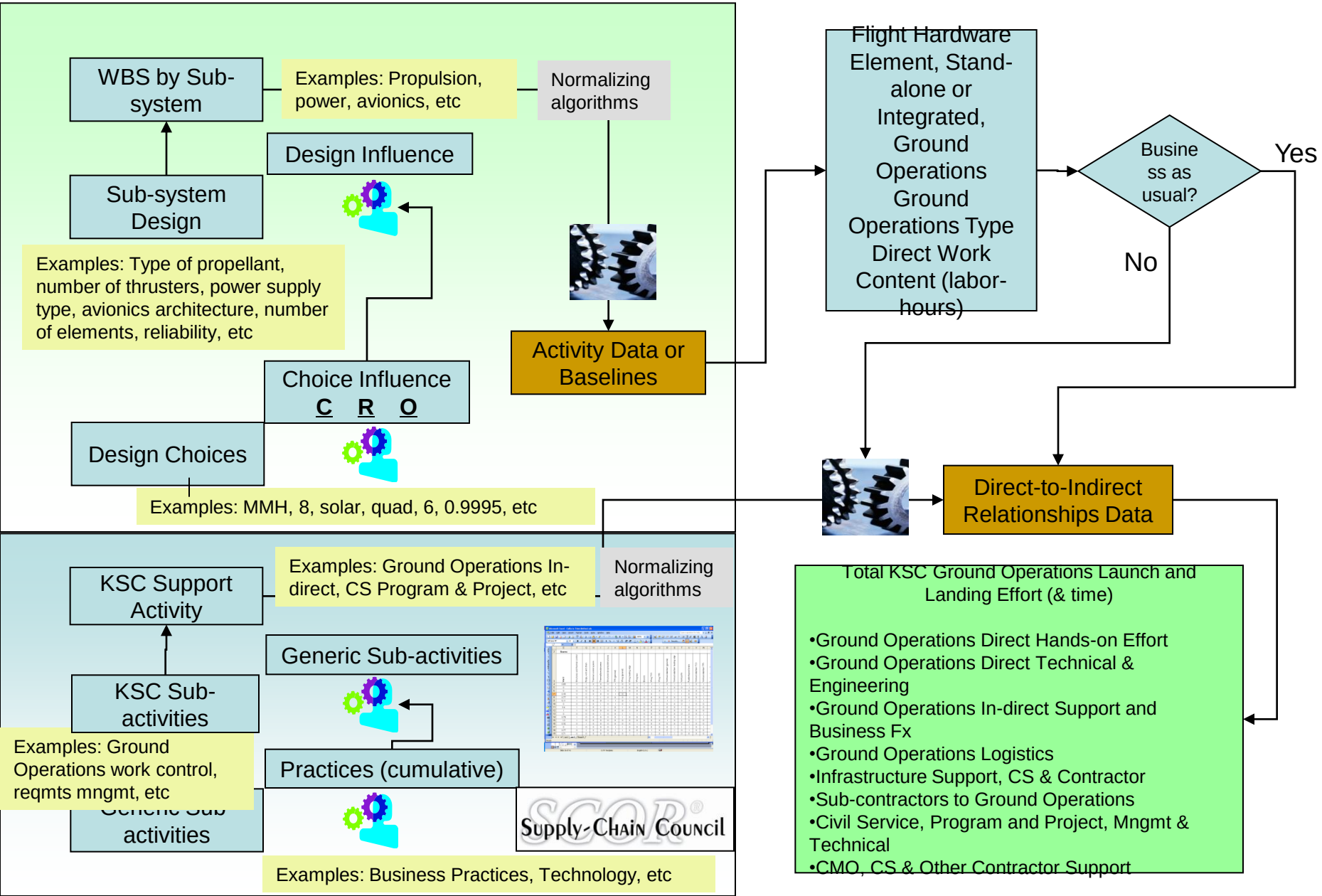
Backup

Ground Operations Modeling, Background
Data

- **LMS Study 2005, Costello, Vision Analytics Inc.**
  - Covers most of the KSC launch and landing only, but excludes ARF, NSLD and others
- **USA Headcount reports; also includes sub-contractors like Wiltech, etc.**
- **FY02 Space Shuttle Program Wall-Chart**
- **Grant Cates “Knowledge Files"**
  - All processing timelines, means, statistically treated, across all KSC activities (MLP turnaround, ARF, VAB stacking, etc) and some non-KSC areas (SRM / UTAH, etc). Raw data plus matching charts.
- **USA SFOC Functional Analysis, (FY 2001 Shuttle Incentive Costs Only), March 14, 2002 (proprietary); only covers about $1.5B of Shuttle program.**
- **Orbiter Upgrade Study Data 2001, Delgado et al**
- **United Space Alliance data compilation, sub-systems labor data from the USA Shop Floor Control System, all sub-systems (flows from the late 90’s)**
  - USA processing data by OMI and activities, grouped as Phases (OPF, VAB, etc) including techs, quality, engineering, mng’mt by activity (the apx. 500,000 labor hours per launch). Approximately ½ the USA workforce.
- **Morris, White, Ebeling, AIAA 96-4245, Analysis of Shuttle Orbiter Reliability and Maintainability Data for Conceptual Studies**
  - Direct processing only, over many flows, by standard sub-system codes, analyzed for averages, deviation, etc
- **Zero-Base Study early 1990’s**
  - Hi-level Fixed/Variable insight by Program Elements such as ET, Launch Ops, Mission Ops, Orbiter, etc
- **Vision Spaceport late 1990’s**
  - More detailed Fixed/Variable insight across entire Shuttle program Level 4/5 budget line items
- **Numerous gap-fillers, too numerous to list…**
  - ARF, NSLD, APU/Hydraulics detailed Studies, numerous TPS data at lo and hi levels, SSME data
  - Best sub-systems insights over the Shuttle program typically from TPS, SSME and APU/Hydraulics; some OMS/RCS, but most other sub-systems have never performed / documented detailed yet comprehensive analysis related to operations figures of merit such as workforce, costs, time-lines / processing drivers, nor relationship within broader context of element processing, such as %, impacts outside sub-system, desired improvements
  - KSC Facility & GSE O&M Maintenance data
    - The apx. $70M a year of only basic O&M by facility

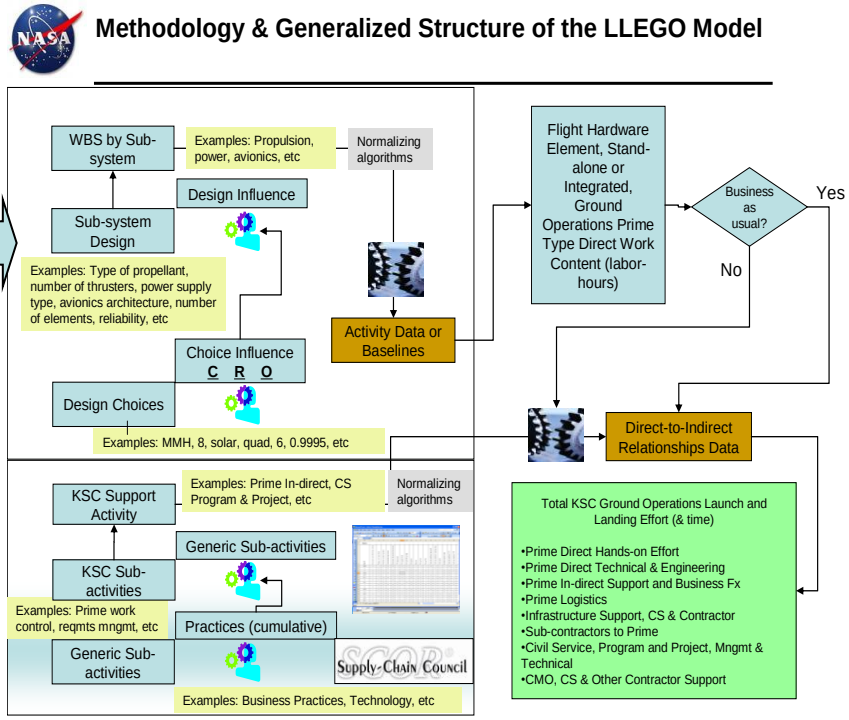
Methodology & General Structure of the LLEGO Model

Description of Influences



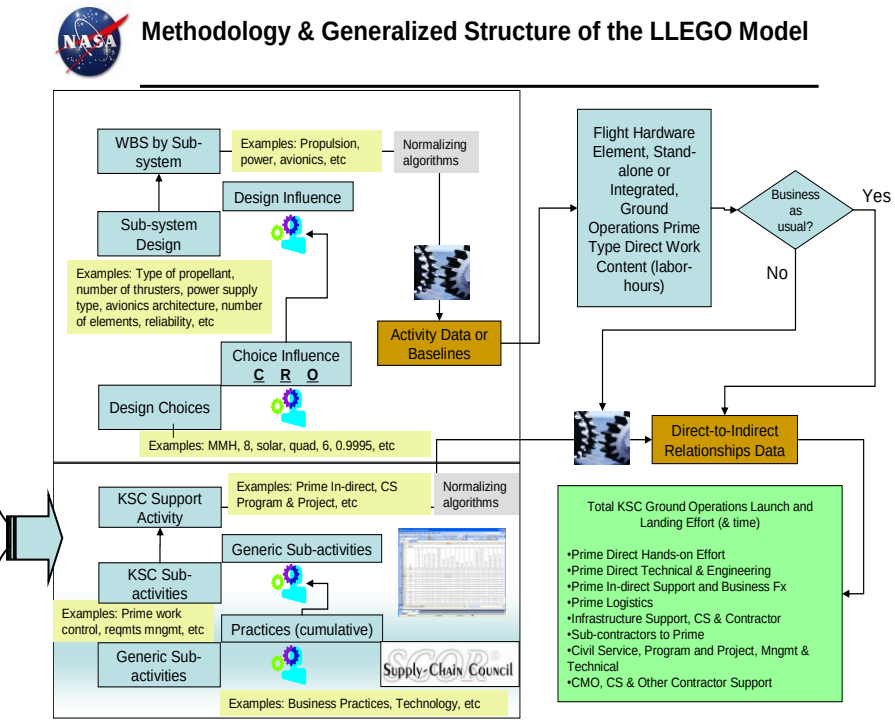
Methodology & General Structure of the LLEGO Model
Description of Influences

- Given design “choice A”, among other possible choices affecting complexity, reliability or operations to degree “x” and…
- …given that choice lies within a series of 1 or more design influences affecting sub-system W to degree “y”…then…
- …adjust the activity data or baseline for that sub-system up or down consistent with the prior design choices

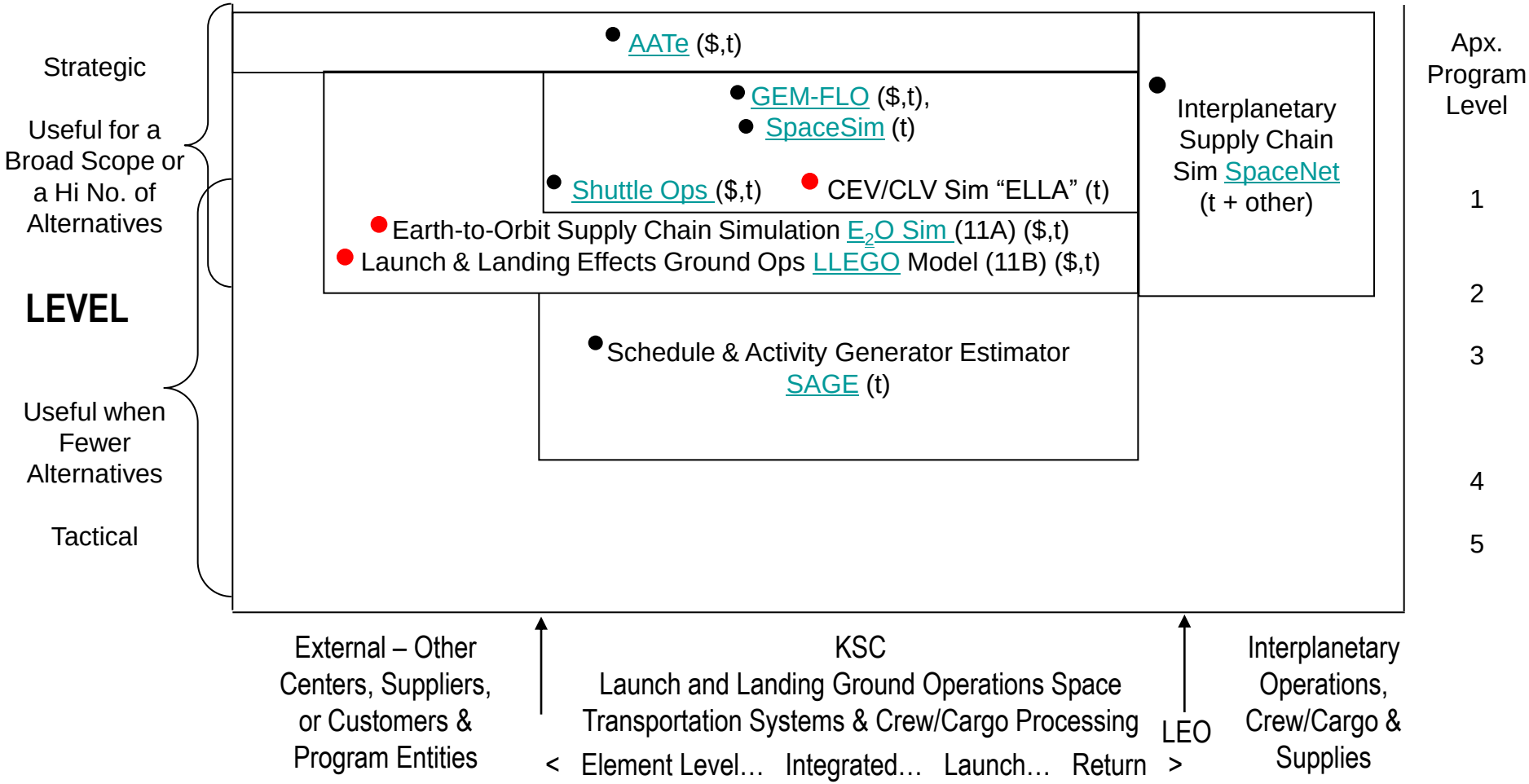


Methodology & Generalized Structure of the Model
Description of Influences

- Given sub-activity “practices A, C and F”, among other possible practices cumulatively affecting a sub-activity to degree “x” and…
- …given that sub-activity lies within a series of sub-activity influences affecting activity area Z to degree “y”…then…
- …adjust the in-direct to direct relationships calculations for activity area Z up or down consistent with the assumption that the specific supply chain practices chosen are implemented



Relation to Other Projects
Past Applications Development



● Available, Past Work ● In Development, Current Work

$-applicable to costs, t-applicable to flow times

Numerous data sources apply at all levels ($ & t) & are often used with/without tools according to analysis needs.

Some tools apply across levels, depending on the depth of analysis desired and the time and resources applied.

Definitions

The Ground Operations Contractor

- **"Ground Operations contractor" as used in this document refers to: A significant contract for a major sub-element of a large program i.e. a future "Ground Operations contractor at KSC".**
  - Does not imply over 50% of total work content, nor over 50% of all contractor only content, though book-keeping of sub-contractors to the Ground Operations contractor may drive the contribution above 50% of total contractor work content.

- **"Ground Operations contractor" term should not be confused with "Prime", except as a way of indicating a significant contract.**
  - The term "prime" is generally used to address an entire program such as Boeing being "the prime contractor, responsible for design, development, construction and integration of the ISS (International Space Station)" and -
  - The term "prime" may also be used by any NASA center lead acquisition, as in the development of a flight element, i.e. Lockheed Martin is the Prime for the construction of the Crew Exploration Vehicle (CEV).

The Ground Operations Contractor

- Content, Ground Operations
  - **Technicians Hands-on Labor**
  - **Engineering, Safety & Quality**
  - **Program Management & Internal Business Functions**
  - **Logistics, Depot Maintenance & Interface to Original Equipment Manufacturers**
  - **Major Sub-contractors to the Ground Operations**
  - **Minor Sub-contractors to the Ground Operations**
  - **Construction (including installation, electrical, construction, development, fabricating, mechanical & misc. contracts overseen by the Ground Operations)**
- Human Space Flight / Space Shuttle "Ground Operations Contractor" is United Space Alliance.
- Capabilities:
  - **Mission, manifest, and trajectory planning and analyses**
  - **On-orbit assembly, payload deployment & servicing**
  - **Extravehicular vehicle activity planning & execution**
  - **Rendezvous/proximity operations & docking**
  - **Space logistics/supply chain management**
  - **Space operations software engineering**
  - **Advanced space flight technology**
  - **Launch & recovery operations**
  - **Flight hardware processing**
  - **Launch vehicle processing**
  - **Mission control operations**
  - **Space systems training**
  - **Sustaining engineering**
  - **Flight crew equipment**
  - **Large-scale integration**
  - **Program/Project Management**

USA
United Space Alliance

2006 Revenue: $1.9 billion

Employees: Approximately 10,000 in Texas, Florida, and Alabama

Not all ground operations. Many other functions.

The Ground Operations Contractor – Technicians Hands-On Labor (Category 1)

- **Definition: Hands-on labor, inclusive of supervisors and shop leads, used principally on "stand-alone" or "integrated" flight hardware elements to accomplish processing, including operations and maintenance tasks on ground systems, usually only dedicated ground support equipment assigned under contract responsibility as directly necessary for flight element processing.**
  - Stand-alone term is interchangeable with "horizontal" and "pre-DD250".
  - Integrated term is interchangeable with "vertical" and "post-DD250".
  - Units=labor-hours.

MORE

- **The term is used here in 2 contexts:**
  - **Actual Labor**: That labor required to accomplish a flow of a specific element from milestone to milestone.
  - **Workforce Labor**: That labor incurred per year, which is dependent on the workforce that is hired resulting from the:
    - Actual labor required
    - Flight rate capability that is sized for
    - The flow time milestone to milestone that is sized for (affected by shifts per day worked)

MORE

- **Total $ of this component are determined by Workforce Labor, NOT Actual Labor (expenses, not costs).**
  - Hiring & firing is typically NOT used in the NASA & contractor paradigm, though steady state ramp ups and ramp downs over periods on the order of 3 to 5 years are realistic.
    - i.e. there is no realism in varying this component year by year for planning purposes just because a planned manifest has 5 launches 1 year, 4 the next, and then 5 again. Each year this component would realistically be the same.

The Ground Operations Contractor – Technicians Hands-On Labor (Category 1)

- **Rule-of-thumb: Unplanned work of 25 to 50% of planned work: Why? (1st instance of question)**
  - Based on numerous distinct data sources.
  - Unplanned work driven by variance, driven by volume, learning curve and technology and design maturity, and the resulting confidence, which also affects planned, pre-emptive work and planned maintenance and checkout flight-to-flight.

- **Assumptions:**
  - Assumes similar technology maturity of the flight elements as to the Space Shuttle, i.e. Space Shuttle like or pedigree of flight & ground systems.
  - Assumes "business as usual" as regards design vs. reliability, that no design is developed toward achieving higher launch rates at a lower cost, i.e. nor increasing the number of test-fail-fix iterations.
  - *If the % relationship is more or less in any proposal, question why? What is different, what improved the hardware ultimately? Most importantly, what improved the operations confidence in the hardware?

- **Key Metrics: Quantity, Utilization**

- **Equations, more detail**

The Ground Operations Contractor – Engineering, Safety & Quality (Category 2)

- **Definition: That technical labor which is in direct support of hands-on labor accomplishing their tasks and which also provides, manages or adds value to technical information to meet requirements, performance, processing, scheduling, constraints and integration across the interfaces of a system. Includes management and supervisors, focused principally on "stand-alone" or "integrated" flight hardware element processing, including operations and maintenance tasks on ground systems, usually only dedicated ground support equipment assigned under contract responsibility as directly necessary for flight element processing.**
  - Stand-alone term is interchangeable with "horizontal" and "pre-DD250".
  - Integrated term is interchangeable with "vertical" and "post-DD250".
  - Units=labor-hours.

MORE

- **Space Shuttle / USA value of ~ 3 to 4:1 vs. technicians workforce labor.**
  - Leans to 3 for non-Orbiter elements.
  - Leans to 4 for Orbiter element.

The Ground Operations Contractor – Engineering, Safety & Quality (Category 2)

- **Rule-of-thumb: 4 to 1: Why? (1st instance of question)**
  - Based on numerous distinct data sources.
  - Mostly because the USA "Equivalent Flow Model" already takes into account both the "hands on" and the "engineering" and the method of determining workforce is such that the ratio rule-of-thumb will yield very similar results more simply if used in the proper domain context (human space flight, plus numerous other caveats below).
  - **Because any bid on a future contract may similarly use as it's basis a 1st order contractual framework of "hands-on" labor-hours to which a similar traditional ratio of "engineering" labor-hours will be applied, even if later adjusted for rationale or caveats.*

- **Assumptions:**
  - Assumes similar technology maturity of the flight elements as to the Space Shuttle, i.e. Space Shuttle like or pedigree of flight & ground systems.
  - Assumes "business as usual" as regards information technology, requirements management, scheduling, configuration control, etc, and especially the flow of information to engineering and to the shop floor, interfacing with this enabling technical support.
  - **If the ratio is more or less in any proposal, question why? What is different, how do each of these changes quantify into changes in the usual ratio seen historically?*

- **Key Metrics: Quantity, Ratio to hands-on**

- **Equations, more detail**

The Ground Operations Contractor – Program Management & Business Functions (Category 3)

- **Definition: These are those functions that are external facing as well as internal facing business in-direct functions. External facing functions usually accomplish a requirement for a customer as part of an associated process. For example, configuration control of work authorization documents is a function required by the customer as part of flight systems ground operations. Internal facing functions are required of any business and are often synonymous with the term "overhead", as for example the function of finances or human resources.**
  - Program interfaces / coordination, rules management (LCC, OMRS, etc)
  - Requirements management and flow-down
  - Generate work documents
  - Configuration management
    - Documentation, authorization, tracking
  - Work control
    - Scheduling
    - Interface tasks into master scheduling and manifest and schedule daily work
  - Dedicated ground systems support, design, planning, and operations and maintenance (O&M)
  - Internal business functions (finance, human resources, payroll & benefits, information systems & networks, purchasing & supplies, environmental management, facilities/office management, other usual and customary internal business charges).

The Ground Operations Contractor – Program Management & Business Functions (Category 3)

- **Rule-of-thumb: Space Shuttle / USA value = ~ 100% of the SUM of Category 1 + Category 2 work-force labor hours. Why? (1st instance of question)**
  - Based on numerous distinct data sources.
    - i.e. half the current USA workforce is neither Category 1 nor Category 2.
    - i.e. apx. 4000 USA employees in the ground operations portion of the USA contract, employees located at KSC, of which roughly half are category 1 and category 2. The rest are in this category.
  - Unable to determine too far into layers the breakout of external to internal functions vs. workforce distribution. Not book-kept this way, albeit such a breakout would be useful as different drivers likely apply.
  - **Because any bid on a future contract may similarly use as it's basis a 1st order contractual framework of "100%" of technicians hands-on + engineering, safety and quality workforce labor.*

- **Assumptions:**
  - Assumes similar technology maturity of the flight elements as to the Space Shuttle, i.e. Space Shuttle like or pedigree of flight & ground systems.
  - Assumes "business as usual" as regards information technology, requirements management, work control, etc, the stated functions, and especially as regards the flow of information among departments and to the shop floor, or to and from engineering and technical support, as well as interfacing with the customer.
  - **If the % is more or less in any proposal, question why? What is different, how do each of these changes quantify into changes in the usual % seen historically?*

- **Key Metrics: Quantity, Ratio to rest of workforce**

- **Equations, more detail**

The Ground Operations Contractor – Logistics, Depot Maintenance (Category 4)

- **Definition: Is that logistics function located close to ground operations, typically as a result of hardware refurbishment, as with reusable or rebuilt elements (solid rocket booster, forward assembly, aft skirt, or orbiter element). Functions to provide an interface from or through the Ground Operations to original equipment manufacturers, other suppliers and program interfaces, and to refurbish and/or test parts, or major part assemblies prior to delivery to the shop floor. Plans and maintains schedules, sources / purchases, tests and / or accepts parts and material, maintains and / or stores inventory, delivers products to the shop floor, and handles (in reverse) receipt of failed or returned parts.**

MORE

- **Space Shuttle / USA value of ~ $175M/year, all Orbiter, ~ 25% labor, rest material.**

MORE

- **Space Shuttle data lacking for equivalent SRB value. Is some % of the ~ $150M total SRB line item (MSFC managed as a portion of the USA sub-contract).**

The Ground Operations Contractor – Logistics, Depot Maintenance (Category 4)

- **Rule-of-thumb: $160/hr of actual technicians hands-on labor - Why? (1st instance of question)**
  - The re-build of SRB forward assemblies or of aft skirts drives a $150M/year operation at KSC. For comparison, the entire ATK / UTAH activity is on the order of $500M/year.
  - Any such activity is essentially a rebuild operation combined with some production.
    - Logistics and production as a recurring operation become inseparably inter-twined. Where does one start, another end – rather arbitrary.
  - Orbiter driven "logistics" line item alone almost approaches 50% of the entire ground operations portion of the contract (by value, not by labor).
    - i.e. much of the cost is spent around the country even if the budget must arrive locally before being spent.
  - Rule-of-thumb relates this value to Category 1 Actual Technicians Hands-on Labor (NOT Workforce Labor) as material and parts flows supporting similar technology likely relate to the work level deriving from the scope with the given technology and design maturity.

- **Assumptions**
  - Assumes similar technology maturity of the flight elements as to the Space Shuttle, i.e. Space Shuttle like or pedigree of flight & ground systems.
  - Assumes "business as usual" as regards information technology, logistics systems, etc, the stated functions, and especially as regards the flow of information between logistics departments and to the shop floor, or to and from engineering and technical support, or to and from program management functions, as well as interfacing with the customer.

- **Key Metrics: Cost, Responsiveness to rest of the system, Ratio Material to Labor by value**

- **Equations, more detail**

The Ground Operations Contractor – Sub-contractors to the Ground Operations (Category 5)

- **Definition: Sub-contractors to the Ground Operations are those contractors which count as headcount to the Ground Operations, albeit within other companies, in general providing services or materials to the Ground Operations that the Ground Operations does not specialize in. For example, rocket engine work may be the domain of Rocketdyne, precision cleaning work the domain of Wiltech, or calibration work the domain of Bionetics.**

MORE

- **Space Shuttle / USA value of ~ $111M/year.**
  - Although not tracked to flight elements, it is likely the most significant drivers are Orbiter, followed by RSRM/RSRB and then by GSE. (i.e. ~ 25% addition in both $ value *and apx. headcount compared to the entire ground ops only Ground Operations portion of the contract value located at KSC of ~ $400M/year).
    - ***i.e. data indicates that the contracts dollar value divided by the headcount overall at the company levels are no different for subs to a Ground Operations than for the Ground Operations.**

MORE

- **Easily overlooked in assigning value to a Ground Operations contract as these sub-contracts may scope later in time.**

MORE

- **Often not-competed per se, as the Ground Operations contractor *must use* certain services at a center.**

MORE

- **New federally mandated small business rules to go into effect in 2012 will dramatically alter the landscape of this category.**
  - http://www.comspacewatch.com/news/viewpr.html?pid=22939

The Ground Operations Contractor – Sub-contractors to the Ground Operations (Category 5)

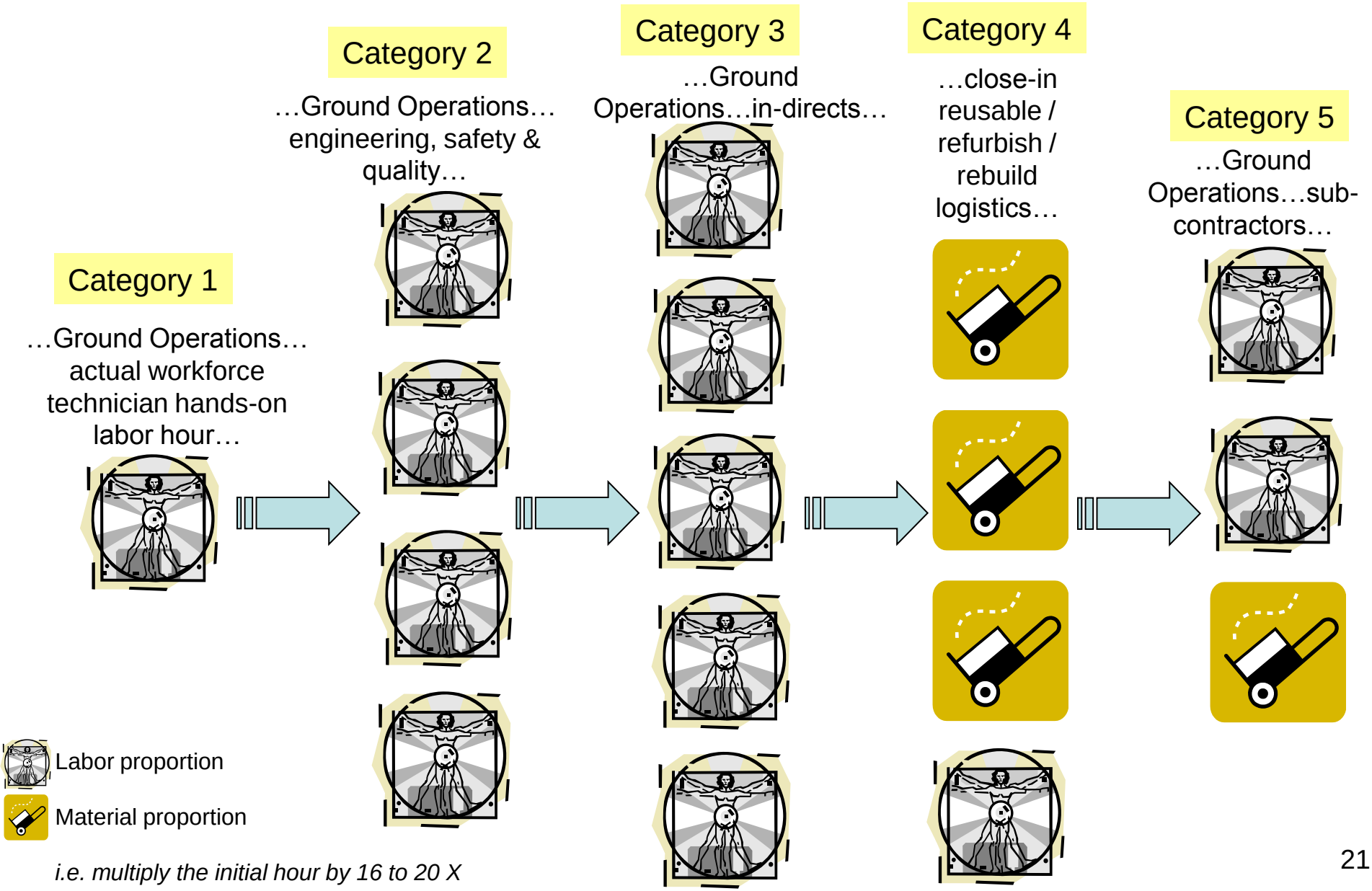
- **Rule-of-thumb: Add a value from 16 to 20% of the total value of the Ground Operations ground operations contract inclusive of the logistics function or apx. 25% if exclusive of the logistics function.**
  - Suggested value of 18.4% addition to the Ground Operations value inclusive of the logistics function.

- **Assumptions:**
  - Assumes similar technology maturity of the flight elements as to the Space Shuttle, i.e. Space Shuttle like or pedigree of flight & ground systems.
  - Assumes "business as usual" as regards the more specialized tasks performed by Florida located sub-contractors, and especially as regards the flow of information between the Ground Operations, the subs and the link back to the requirements interfacing with the customer which defines by requirements both technical and contractual (who to use) and thus much of the scope of the subs.
  - **If the % is more or less in any proposal, question why? What is different, how do each of these changes quantify into changes in the usual % seen historically?*

- **Key Metrics: Cost, Responsiveness to rest of the system, Ratio to Ground Operations Content**

- **Equations, more detail**

Visually… (Re. Ground Operations Contractor ONLY Category 1 thru 5 Definitions)



The Customer

NASA Program & Project Management (Category 6)

- **Definition: NASA Program & Project Management, oversees or has insight into the fulfillment of requirements by the flight or ground element contractor and into the ground operations elements such as facilities and ground support equipment that are required to prepare, integrate and launch a flight system. The role may be more oversight, or more in-depth, early in a program vs. later due to confidence and program maturity, or due to the nature of development vs. operations.**

MORE

- **Data here can be interpreted many ways as early programs structure had most of the NASA civil service at centers covered by a program (i.e. Space Shuttle and Space Operations Directorate kept the space ops centers full-time-equivalents fully funded; no real attempt to trace back to work content exists pre-full-cost accounting).**

NASA Program & Project Management (Category 6)

MORE

- **"FTE" (civil service full time equivalents) center ceilings are fixed.**

MORE

- **New programs can expect to be *required* to use this resource as older programs such as the Space Shuttle or the International Space Station transition.**
  - ISS transitions post 2010 from major additions to the structure of the station, that is construction mode, to a mode of use and lesser operations and upgrade paths.

Workforce Estimates by Installation

	FTE Estimates						
Center	**FY 2006**	**FY 2007**	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**	**FY 2012**
Ames Research Center	1240	1210	1136	1085	1085	1085	1082
Dryden Flight Research Center	477	515	535	520	501	488	487
Glenn Research Center	1667	1646	1620	1595	1595	1595	1590
Goddard Space Flight Center	3284	3193	3100	3100	3100	3100	3091
Johnson Space Center	3235	3265	3265	3258	3255	2899	2890
Kennedy Space Center	2066	2100	2107	2107	2107	1902	1894
Langley Research Center	1934	1920	1854	1800	1800	1800	1794
Marshall Space Flight Center	2527	2569	2569	2550	2500	2500	2492
Stennis Space Center	269	282	282	280	280	280	279
Headquarters	1318	1280	1292	1300	1300	1300	1242
NSSC	64	120	140	156	159	159	159
NASA	**18,081**	**18,100**	**17,900**	**17,751**	**17,682**	**17,108**	**17,000**

Note: Distribution of Center FTE by Mission Directorate not available.

KSC Civil Service Workforce = ~ 2100 personnel

From the FY 2008 NASA Budget Request
http://www.nasa.gov/about/budget/index.html

NASA Program & Project Management (Category 6)

MORE

- **Breakout:**
  - ~ 550 civil service people Space Shuttle project support, launch & landing per se
    - ~ $50M a year according to separate data source.
  - ~ 170 civil service people Space Shuttle program level, but physically located at KSC (i.e. program office like functions)
  - ~ 830 civil service people within the new “CMO” category at KSC.
    - The same data source as for the prior also shows ~ $327M/year cost
    - Prior cost also covers 1698 contractors.
    - i.e. 49% in addition to contractor headcount.
    - i.e. WYE:FTE ratio = 2.1.
  - Total accounted for here = 550+170+830=1550
  - Rest of CS at KSC would be “other programs” such as International Space Station element processing for launch, Launch Services Program (LSP) and other activities (such as Constellation Ground Operations Element).
    - i.e. Remainder = 2100 – 1550 = 550 civil service personnel
    - NOTE: A portion of the CS above, in the 1550 headcount, in the CMO portion, also work all these other programs.

NASA Program & Project Management (Category 6)

MORE

- **Implications:**
  - Constellation Ground Operations Element (GOE) can expect to have *available*, minimally, in addition to any current workforce:
    - 550 + 170 + TBD number of ISS civil service personnel.
    - Portion of these may perform duties for other centers, as in program management (the current 170).
    - Most of the current 832 CS people in the CMO activities would also be *available* to be used by Constellation GOE.

"He discussed past efforts to drive some NASA centers to extinction, how that is politically impossible, and that the Agency must manage programs and institutions taking that fact into account. Missions need to plan out work so that the Agency knows what people it needs. Centers need to manage their workforce to provide for mission needs."

Mike Griffin, NASA Strategic Management Council 22 May 2007: Griffin Comments on Agency Strategy

NASA Program & Project Management (Category 6)

- **Rule-of-thumb: Any rule-of-thumb must not ignore the requisite reality of program maturity and confidence. A rule-of-thumb likely to yield realistic results would be of the form:**
  - Early years of a program, years 1-5, **2 times X%** of Ground Operations content (including logistics and sub-contractors to the Ground Operations). Oversight phase.
  - Mid years of a program, years 5-15, **1.5 times X%** of Ground Operations content (including logistics and sub-contractors to the Ground Operations). Learning Phase.
  - Mature years of a program, years 15 +, **X%** of Ground Operations content (including logistics and sub-contractors to the Ground Operations). Insight Phase.
    - X is likely in the 10% range.

- **Assumptions:**
  - Work levels near historical at a total center level.
    - i.e. KSC Space Shuttle as a $1.4B a year expense (excluding some areas such as the RSRM/RSRB ARF).

- **Key Metrics: Program year, programs at the same center, total FTE ceiling**

- **Equations, more detail**

NASA & Contractors Center Management & Operations (Category 7)

- **Definition: Represents institutional functions at each center. These are functions mandated generally at an agency level or a federal level. Examples include procurement, finance, human resources, environmental management, facility services, information technology and services, security, and safety and mission assurance.**
  - Include both civil service and contractors supporting these institutional functions.

MORE

- **As of changes in full-cost-accounting occurring in 2006 the "CMO" is no longer a calculated tax on programs & projects.**
  - Change in semantics was meant to address the NASA centers "uncovered capacity issues".
  - CMO represents areas previously called "G&A" + "Service Pools" (up to & including FY 2005).
  - May be useful at times to consider as analogous to the customers version of "The Ground Operations Contractor – Program Management & Business Functions (Category 3)" costs.

NASA & Contractors Center Management & Operations (Category 7)

MORE

- **Sample from the FY 2006 budget summary, showing only the G&A component that later went into the CMO component (i.e. does not include service pools):**

ion in the critical Center infrastructure required to support the *Vision for Space Exploration*.

Center	FY 2006 ($ in millions)
Ames Research Center	191
Dryden Flight Research Center	40
Glenn Research Center	161
Goddard Space Flight Center	214
Johnson Space Center	207
Kennedy Space Center	232
Langley Research Center	195
Marshall Space Flight Center	226
Stennis Space Center	39
Total, Center G&A	**1,505**

include Headquarters operations and Agency-wide functions. FY 2006

KSC $232M/year
(does not include service pools)

NASA & Contractors Center Management & Operations (Category 7)

MORE

- **Sample from the FY 2008 budget request showing the entire CMO component:**
  - Also re. slide on NASA program & Project Management

KSC FY 2008 est. $325M/year

(does include what were once called service pools)

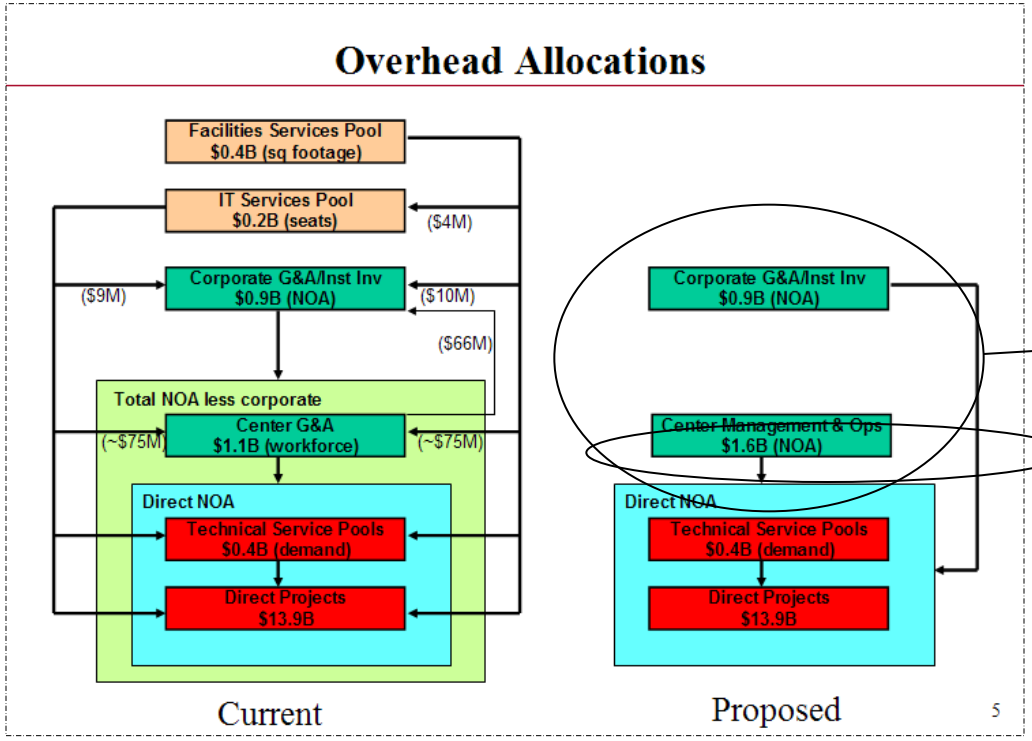
Kennedy Space Center	1,454.50	1,320.20	1,214.40	1,548.20	1,599.10
Center Management & Operations	324.9	336.6	342.5	347	354.9
Corporate G&A	8.6	8.7	8.8	8.8	8.8
Institutional Investments	44.8	38.6	44.9	48.9	44.9
Mission Programs	1,076.00	936.2	818.2	1,143.50	1,190.40

From the FY 2008 NASA Budget Request
http://www.nasa.gov/about/budget/index.html

NASA & Contractors Center Management & Operations (Category 7)

MORE

- **At an agency level, from "Full Cost Implementation Simplification" (Janice Robertson, May 23, 2006): Total across NASA for this category is ~**



Agency Level Sum
$0.9B + $1.6B = $2.5B/yr

Re. $1.5B previous table

NASA & Contractors Center Management & Operations (Category 7)

MORE

- **Still in range of $300M even after Space Shuttle last flight.**
  - All centers shown as relatively stable on this line item.

KSC FY 2012 est. $326M/year

Center Management & Operations	$1,599.5	$1,650.7	$1,674.7	$1,667.4	$1,680.5	$1,680.5
ARC	140.1	144.9	139.1	139.6	144.3	144.3
DFRC	45.1	45.6	45.4	45.6	43.0	43.0
GRC	131.7	137.6	139.1	141.8	145.2	145.2
GSFC	263.4	279.9	287.9	301.3	310.5	310.5
JSC	290.0	305.0	305.3	288.4	286.2	286.2
KSC	302.7	311.9	327.4	327.0	326.1	326.1
LaRC	152.5	148.2	147.3	148.2	146.9	146.9
MSFC	226.7	228.2	232.6	225.3	226.6	226.6
SSC	47.3	49.4	50.6	50.2	51.7	51.7
TOTAL NASA	$16,792.3	$17,309.4	$17,614.2	$18,026.3	$18,460.4	$18,905.0

From the FY 2007 NASA Budget Planning Guidance

- **Even though it's supposed to be fixed, it will still be allocated!**
  - Supports rule-of-thumb to follow >

Center M&O will be directly budgeted and allocated to program budgets at the completion of the budget development process, in accordance with each project's pro rata share of the total Direct New Obligation Authority (NOA) at the Center. Final allocations will adjust the total full cost program budgets, but will not require adjustments to the direct program budgets. Corporate overhead accounts do not receive any Center M&O allocations.

From the FY 2007 NASA Budget Planning Guidance

NASA & Contractors Center Management & Operations (Category 7)

- **Rule-of-thumb: Programs have been freed from accounting for this as a cost allocated to a program, but to the extent that work at any center requires such support, sizing of the amount of CMO resource a program is likely to "draw on" can be done by taking a % of Ground Operations + logistics + subcontractors (Category 1, 2, 3, 4, + 5) + NASA Program & Project Management (Category 6).**
  - Relates draw to related work content that is enabled.
  - i.e. 33% addition by dollar amount to the Sum of Category 1 thru 6 by dollar amounts.

- **Assumptions:**
  - Assumes similar technology maturity of the flight elements as to the Space Shuttle, i.e. Space Shuttle like or pedigree of flight & ground systems.
  - Assumes "business as usual" processes as regards institutional functions, management, & the information technologies or systems employed to support these processes. Especially affected by the flow of information between programs and the institution, regulations, and process strategies and maturity.

- **Key Metrics: Program year, programs at the same center, total FTE ceiling, contractor supporting workforce**

- **Equations, more detail**

KSC Infrastructure (Category 8)

- **KSC Infrastructure: Is that infrastructure most removed from day-to-day operations but enabling of flight & ground systems functions required for processing through launch. Examples include base operations, communications, and ground operations logistics.**
  - Base operations often referred to as “JBOSC” but the nature of contracting for joint base operations support is changing in FY 2008 as to contracts & management approach.

MORE

- **Space Shuttle / KSC value of ~ $200M/year.**

MORE

- **Much research required in this area as likely high fixed costs likely to hit programs used to paying by the yard.**
  - Paying by the yard is implemented in acquisition mechanisms but obscures that this sale is enabled and occurs only when another customer has already paid for the availability of the bolt of cloth.

KSC Infrastructure (Category 8)

- **Rule-of-thumb: Many rules may apply –**
  1. Fixed cost of apx. $200M a year for KSC that must be covered, in reverse, by proportional allocation to existing program customers.
     - Example: IF Constellation is at some time 80% of the content at KSC, with the remainder "other" such as Launch Services Program, then the KSC Infrastructure that would end up being the responsibility of the program (if not in addition to CMO) would be an additional $160M per year.
     - Because "Infrastructure" serves ALL, as a % percent based on Ground Operations (incl. logistics), + Ground Operations Subcontractors + Civil Service + CMO content
       - Add ~ 18% to previous sum.
  2. As an evolving cost to a program, and a risk:
     - Example: Fixed at $200M a year with evolving Program and Institutional coverage after reassessment of assets (disposition of assets may be "active", "in-active", "stand-by", "moth-balled" or "abandoned", each with differing cost consequences to operations, re. NPR 8800.15A).

- **Assumptions:**
  - Assumes similar technology maturity of the flight elements as to the Space Shuttle, i.e. Space Shuttle like or pedigree of flight & ground systems.
  - Assumes "business as usual" processes as regards institutional functions, management, & the information technologies or systems employed to support these processes. Especially affected by the flow of information between programs and the institution, regulations, and process strategies and maturity.

- **Key Metrics: Program year, programs at the same center, total FTE ceiling, contractor supporting workforce**

- **Equations, more detail**

Data, Relationships & Equations

Return to Definition

- **Ground Operations Contractor – Technicians Hands-on Labor (Category 1 – C1)**
  - May be derived bottoms-up, querying flight & ground sub-systems experts.
  - May be derived top-down, by comparison to historical, analogous data (similar to rule-of-thumb, below).

- **Equations of interest:**

f = single flow time in work days that results = C1 / (b * c * 8)
Example: f = 15,000 / (2 * 23 * 8) = ~ 41 work days per flow

g = flow time that is required to be consistent with the launch rate targeted per year = 365 / d
Example: 6 launches per year requires ~ 60 calendar day flows for this element, or ~44 work-day flows.

NOTE: IF f > g, either more workforce must be hired and bought in per shift for this element, or another parallel crew must be working at the same time as the first on another flight element with associated ground system support.

C1' = workforce labor for the year = *c * b * 2080 * i*
Example: 23 * 2 * 2080 * 1 = 95,680 labor-hours for the year

j = utilization for this workforce element = *(C1 * d) / C1'*
Example: (15,000 * 6) / 95,680 = 94%

C1 = actual labor required per flow (labor-hours)
b = shifts per day (1 – 3)
c = workforce to bring in per shift, i.e. headcount per shift per flow in work
d = flows per year sized for, determined by launch rate
e = labor per work day that can be applied
f = single flow time in work days that results
g = flow time that is required to be consistent with the launch rate targeted per year
C1' = workforce labor for the year
i = number of crews working a flow in parallel
j = utilization for this workforce element

Data, Relationships & Equations

Return to Definition

- **Ground Operations Contractor – Technicians Hands-on Labor (Category 1 = C1)**
  …continued

- **Assumptions:**
  - Assumes any actual labor required per flow, in estimation, has already accounted for both productive and non-productive hours, and thus the use of an 8 hour day is adequate for this calculation (cancels out)
  - Launch rate assumes steady state
  - Assumes 5 work days per week. This can vary in actual operations but is a sound assumption for estimation purposes.

- **Caveats:**
  - Utilization is not the same as productivity, productive and un-productive hours having been assumed to be accounted for in any in-going actual labor required per flow estimate.

- **Data Link (hyperlink when that section done)**

Data, Relationships & Equations

Return to Definition

- **Ground Operations Contractor – Engineering, Safety and Quality (Category 2 = C2)**
  - May be derived bottoms-up, querying flight & ground sub-systems experts, sub-system by sub-system of a given flight element.
  - May be derived top-down, by comparison to historical, analogous data (similar to rule-of-thumb, below).

- **Equations of interest:**

$$C2 = K * C1'$$

C2 = Engineering, Safety and Quality Workforce Labor for the Year (labor-hours)
C1' = Same company, Ground Operations contractor Technician Workforce Labor for the Year (labor-hours)
(NOT actual labor for the year C1; this would require an adjusted ratio).
K = Ratio rule-of-thumb:
Suggest = 3.2, all flight elements, in early definition
Suggest = 3 for simpler flight elements
Suggest = 4 for more complex crewed flight elements

- **Assumptions:**
  - Re. definitions

- **Caveats:**
  - Drivers (hyperlink when that section done), in-going organizational, process or technology parameters in the operation or the supply chain, can change the basis of this ratio. i.e. a new work control system, a new drawing system, etc.
  - Fixed costs must be considered. There is likely a lower bound to altering this rule-of-thumb.

- **Data Link (hyperlink when that section done)**

Data, Relationships & Equations

Return to Definition

- **Program Management & Business Functions (Category 3 = C3)**
  - May be derived bottoms-up, querying organizational experts who will assess the business processes being sized and complement these with internal charges as applicable overheads from experience.
  - May be derived top-down, by comparison to historical, analogous data (similar to rule-of-thumb, below).

- **Equations of interest:**

$$C3 = L * (C1' + C2)$$

C3 = Program Management & Business Functions (labor-hours) for the Year
C1' = Same company, Ground Operations contractor Technician Workforce Labor for the Year (labor-hours)
C2 = Engineering, Safety and Quality Workforce Labor for the Year (labor-hours)
L = % rule-of-thumb:
Suggest = 100%, all flight elements, in early definition

- **Assumptions:**
  - Re. definitions

- **Caveats:**
  - Drivers (hyperlink when that section done), in-going organizational, process or technology parameters in the operation or the supply chain, can change the basis of this ratio. i.e. a new requirements verification process, new work planning processes, new ordering system, etc.
  - Fixed costs must be considered. There is likely a lower bound to altering this rule-of-thumb.

- **Data Link (hyperlink when that section done)**

Data, Relationships & Equations

Link TBD

- **Calculating the value of Purchasing an Amount of Ground Operations Labor-Hours (Category 1, 2 + 3)**
  - Text
  - Text
  - Text
  - Text
- **Equations of interest:**

IN REVIEW

a = M * tbd sensitive rate?

a = tbd wording
. = tbd
. = tbd
M = "Rate" rule-of-thumb:
Suggest =

- **Assumptions:**
  - Re.
- **Caveats:**
  - text
- **Data Link (hyperlink when that section done)**

Data, Relationships & Equations

Return to Definition

- **The Ground Operations Contractor – Logistics, Depot Maintenance (Category 4 = C4)**
  - May be derived bottoms-up, querying logistical experts who will assess the effort, especially the scheduled refurbishment and the expected failures, and the material costs being sized, and complement these with internal charges as applicable labor and overheads from experience.
  - May be derived top-down, by comparison to historical, analogous data (similar to rule-of-thumb, below).

- **Equations of interest:**

$$C4 = N * (C1 * d)$$

C4 = The Ground Operations Contractor – Logistics, Depot Maintenance ($ dollars, labor & materials, for the year)
C1 = actual labor required per flow (labor-hours)
d = flows per year sized for, determined by launch rate
N = "Rate" rule-of-thumb:

Suggest = $160/hr, only applicable flight elements, close in logistics support at the ground operations location, refurbished / rebuilt or reused elements only, in early definition.

- **Assumptions:**
  - Re. definitions

- **Caveats:**
  - Drivers (hyperlink when that section done), in-going organizational, process or technology parameters in the operation or the supply chain, can change the basis of this ratio. i.e. a new requirements verification process, new work planning processes, new ordering system, etc.
  - Fixed costs must be considered. There is likely a lower bound to altering this rule-of-thumb.

- **Data Link (hyperlink when that section done)**

Data, Relationships & Equations

Return to Definition

- **The Ground Operations Contractor – Sub-contractors to the Ground Operations (Category 5 = C5)**
  - May be derived bottoms-up, assessing both requirements scope as well as the existing cost of services expected, by project subject matter experts, as well as in conjunction with the Ground Operations (to whatever legal extent allowed), especially considering any major contractual items specifically excluded from the Ground Operations or services that are assumed specialized and to be performed by companies that already provide such services in Human Space Flight operations.
  - May be derived top-down, by comparison to historical, analogous data (similar to rule-of-thumb, below).

- **Equations of interest:**

$$C5 = P * a$$

C5 = The Ground Operations Contractor – Sub-contractors to the Ground Operations ($ dollars for the year)
a = Total value of Ground Operations contract (Category 1, 2 & 3) + logistics (Category 4)
P = % rule-of-thumb:

Suggest = 18.4%
Suggest any other derivation cross check to see if resulting value in range of 16 to 20%.

- **Assumptions:**
  - Re. definitions

- **Caveats:**
  - Drivers (hyperlink when that section done), management of specialized tasks performed by Florida located sub-contractors, and especially as regards the flow of information between the Ground Operations, the subs and the link back to the requirements interfacing with the customer which defines by requirements both technical and contractual (who to use) and thus much of the scope of the subs.
  - Fixed costs must be considered. There is likely a lower bound to altering this rule-of-thumb.

- **Data Link (hyperlink when that section done)**

Data, Relationships & Equations

Return to Definition

- **NASA Program & Project Management (Category 6 = C6)**
  - Dependent on workforce constraints
    - Available workforce may be more or less than required but inalterable due to civil service hiring and firing policy, policy for using civil service workfoirce first and contractors as content above that, and that content is always significantly greater than the avilable civil service workforce.
    - Does not address skills

- **Equations of interest:**

$$C6 = Q * (a + C4 + C5)$$

C6 = NASA Program & Project Management workforce ($ per year)
C4 = The Ground Operations Contractor – Logistics, Depot Maintenance ($ dollars, labor & materials, for the year)
C5 = The Ground Operations Contractor – Sub-contractors to the Ground Operations ($ dollars for the year)
Q = % rule-of-thumb:

Suggest = 19.7% Years 15+ of operation (exclude development)
Suggest = 14.8% Years 5-15 of operation (exclude development)
Suggest = 9.9% Years 1-5 of operation (exclude development)

- **Assumptions:**
  - Re. definitions

- **Caveats:**
  - Must add up considering and consistent with other center content for the civil service workforce including CMO and other programs at the center.

- **Data Link (hyperlink when that section done)**

Data, Relationships & Equations

Return to Definition

- **NASA & Contractors Center Management & Operations (Category 7 = C7)**
  - Extremely difficult to derive bottoms up as it requires a sense of each activity as a service and an amount that can be purchased or assigned and allocated to a customer.
  - Usually derived as a tax varying according to draw, but recent accounting changes have eliminated that approach as well as too far disconnected from fixed costs.
  - A sense of the program's draw or pressure (or lack thereof on this type resource may be derived top-down, by comparison to historical, analogous data (similar to rule-of-thumb, below).

- **Equations of interest:**

$$C7 = R * (a + C4 + C5 + C6)$$

C7 = NASA & Contractors Center Management & Operations @ KSC ($ per year)
C4 = The Ground Operations Contractor – Logistics, Depot Maintenance ($ dollars, labor & materials, for the year)
C5 = The Ground Operations Contractor – Sub-contractors to the Ground Operations ($ dollars for the year)
C6 = NASA Program & Project Management workforce ($ per year)
R = % rule-of-thumb:

Suggest = 33%

Suggest value of this calculation is to cross check to see what portion of KSC CMO FY 2007 of apx. $262M per year is not covered, i.e. the difference from $262M.

- **Assumptions:**
  - Re. definitions

- **Caveats:**
  - Fixed costs must be considered. There is likely a lower bound to altering this function and this rule-of-thumb.

- **Data Link (hyperlink when that section done)**

Data, Relationships & Equations

Return to Definition

- **KSC Infrastructure (Category 8 = C8)**
  - Extremely difficult to derive bottoms up as it requires a sense of each activity as a service and an amount that can be purchased or assigned and allocated to a customer.
  - New methods will need to evolve within a program to fully appreciate the impact of this category. NOT LIKE CMO. Infrastructure migrates back to the institution after a program ends.
  - Only institutions can disposition assets, not programs i.e. the Space Shuttle program can not "moth-ball" a facility or any re-categorization for that matter. Only an institution can do this after it receives that facility back from the program.
  - Deciding not to use something takes resources. Environmental disposition, again, even to do nothing, may trump any planned savings. Beware. Justifying doing nothing takes studies, etc meeting requirements of the disposition process.
  - A sense of the program's draw or pressure (or lack thereof on this type resource may be derived top-down, by comparison to historical, analogous data (similar to rule-of-thumb, below).

- **Equations of interest:**

$$C8 = S * (a + C4 + C5 + C6 + C7)$$

C8 = KSC Infrastructure charges ($ dollars per year)
C4 = The Ground Operations Contractor – Logistics, Depot Maintenance ($ dollars, labor & materials, for the year)
C5 = The Ground Operations Contractor – Sub-contractors to the Ground Operations ($ dollars for the year)
C6 = NASA Program & Project Management workforce ($ per year)
C7 = NASA & Contractors Center Management & Operations @ KSC ($ per year)
S = % rule-of-thumb:
Suggest = 18%
Suggest value of this calculation is to cross check to see what portion of KSC Infrastructure of apx. $200M per year is not covered, i.e. the difference from $200M.

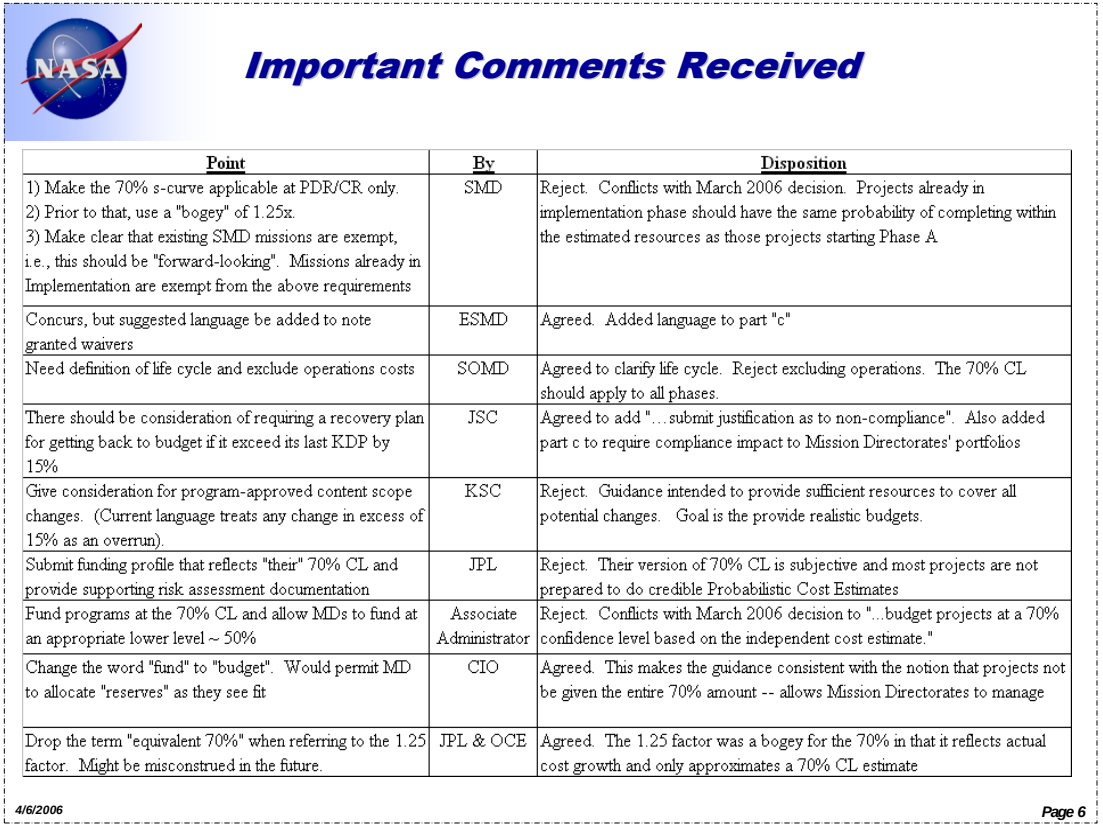
- **Assumptions:**
  - Re. definitions
- **Caveats:**
  - Fixed costs must be considered. There is likely a lower bound to altering this rule-of-thumb.
- **Data Link (hyperlink when that section done)**

Summary Points – Equations & Estimating the Ground Operations Element

- **The estimate will never be right (enough).**
- **No one ever built what anyone else ever estimated**
- **Purpose of the prior descriptive model & equations is to guide a process for insight, then as guidance for developing actions stemming from those insights:**
  - Process: Ask why again…
  - Action: Ask why not…new paths.

Summary Points – Equations & Estimating the Ground Operations Element

- **Realism is the goal.**



Important Comments Received

Point	By	Disposition
1) Make the 70% s-curve applicable at PDR/CR only. 2) Prior to that, use a "bogey" of 1.25x. 3) Make clear that existing SMD missions are exempt, i.e., this should be "forward-looking". Missions already in Implementation are exempt from the above requirements	SMD	Reject. Conflicts with March 2006 decision. Projects already in implementation phase should have the same probability of completing within the estimated resources as those projects starting Phase A
Concurs, but suggested language be added to note granted waivers	ESMD	Agreed. Added language to part "c"
Need definition of life cycle and exclude operations costs	SOMD	Agreed to clarify life cycle. Reject excluding operations. The 70% CL should apply to all phases.
There should be consideration of requiring a recovery plan for getting back to budget if it exceed its last KDP by 15%	JSC	Agreed to add "…submit justification as to non-compliance". Also added part c to require compliance impact to Mission Directorates' portfolios
Give consideration for program-approved content scope changes. (Current language treats any change in excess of 15% as an overrun).	KSC	Reject. Guidance intended to provide sufficient resources to cover all potential changes. Goal is the provide realistic budgets.
Submit funding profile that reflects "their" 70% CL and provide supporting risk assessment documentation	JPL	Reject. Their version of 70% CL is subjective and most projects are not prepared to do credible Probabilistic Cost Estimates
Fund programs at the 70% CL and allow MDs to fund at an appropriate lower level ~ 50%	Associate Administrator	Reject. Conflicts with March 2006 decision to "…budget projects at a 70% confidence level based on the independent cost estimate."
Change the word "fund" to "budget". Would permit MD to allocate "reserves" as they see fit	CIO	Agreed. This makes the guidance consistent with the notion that projects not be given the entire 70% amount -- allows Mission Directorates to manage
Drop the term "equivalent 70%" when referring to the 1.25 factor. Might be misconstrued in the future.	JPL & OCE	Agreed. The 1.25 factor was a bogey for the 70% in that it reflects actual cost growth and only approximates a 70% CL estimate

Implementing Budgets that Reflect 70% Confidence Level Estimates

Resolution of Strategic Planning Guidance Comments

May 22, 2007

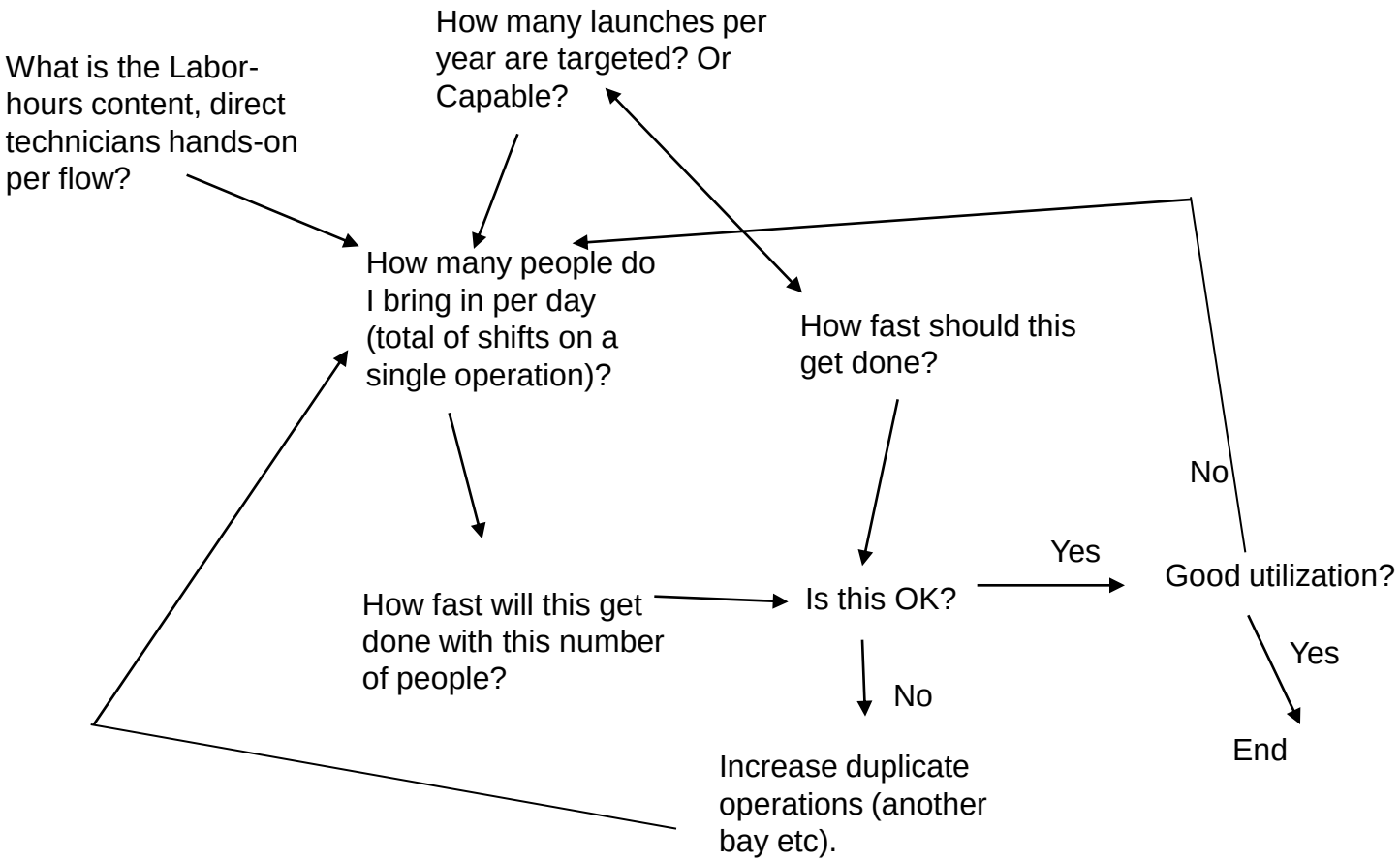
Comment:
"Give consideration for program approved content scope changes…

Reject

…Guidance intended to provide sufficient resources to cover all potential changes. Goal is to provide realistic budgets"

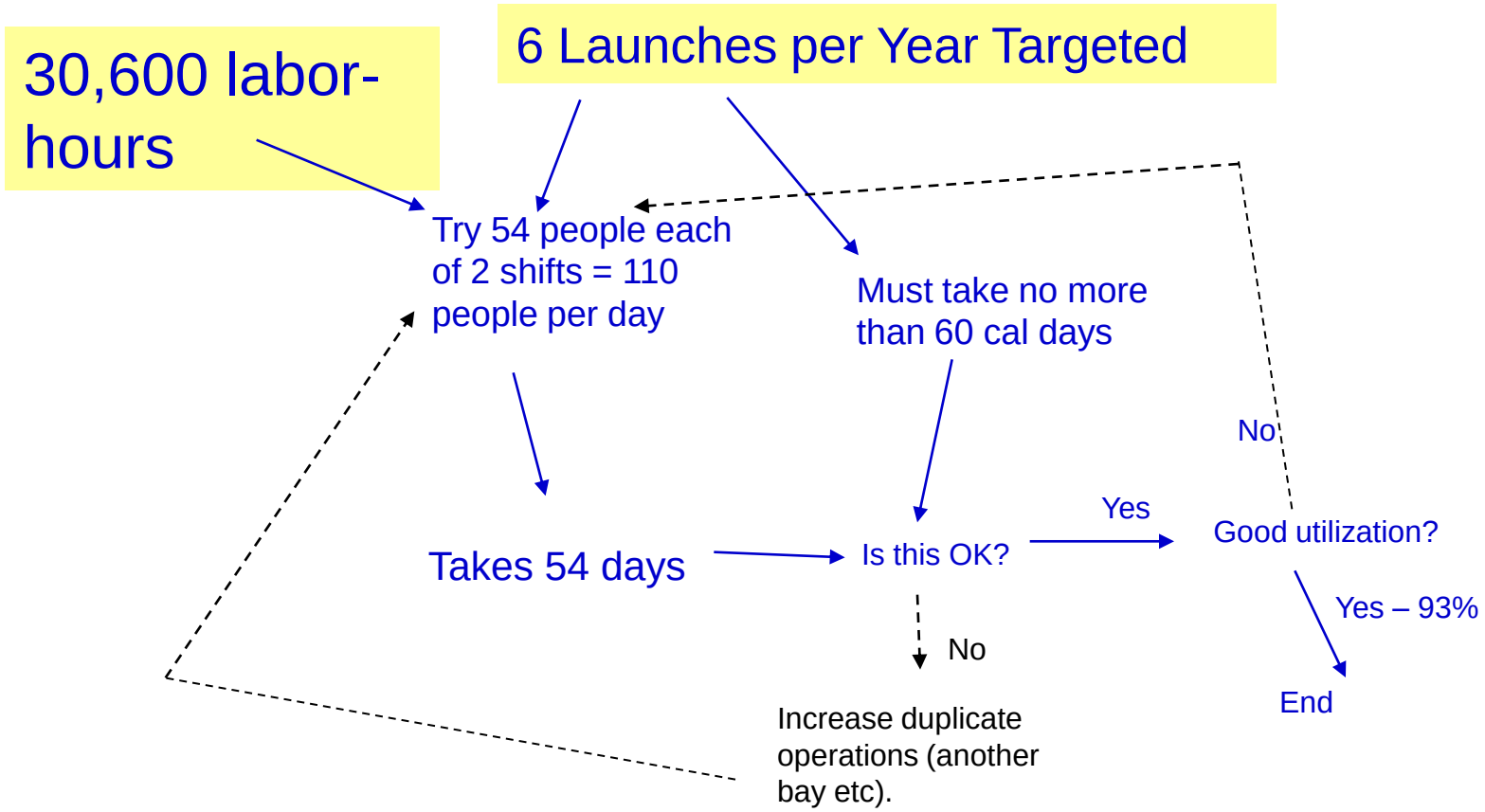
Potential Experiments & Analysis Approach – Families of Curves

- **Driving to outcomes that are "consistent" (not the same as "correct").**



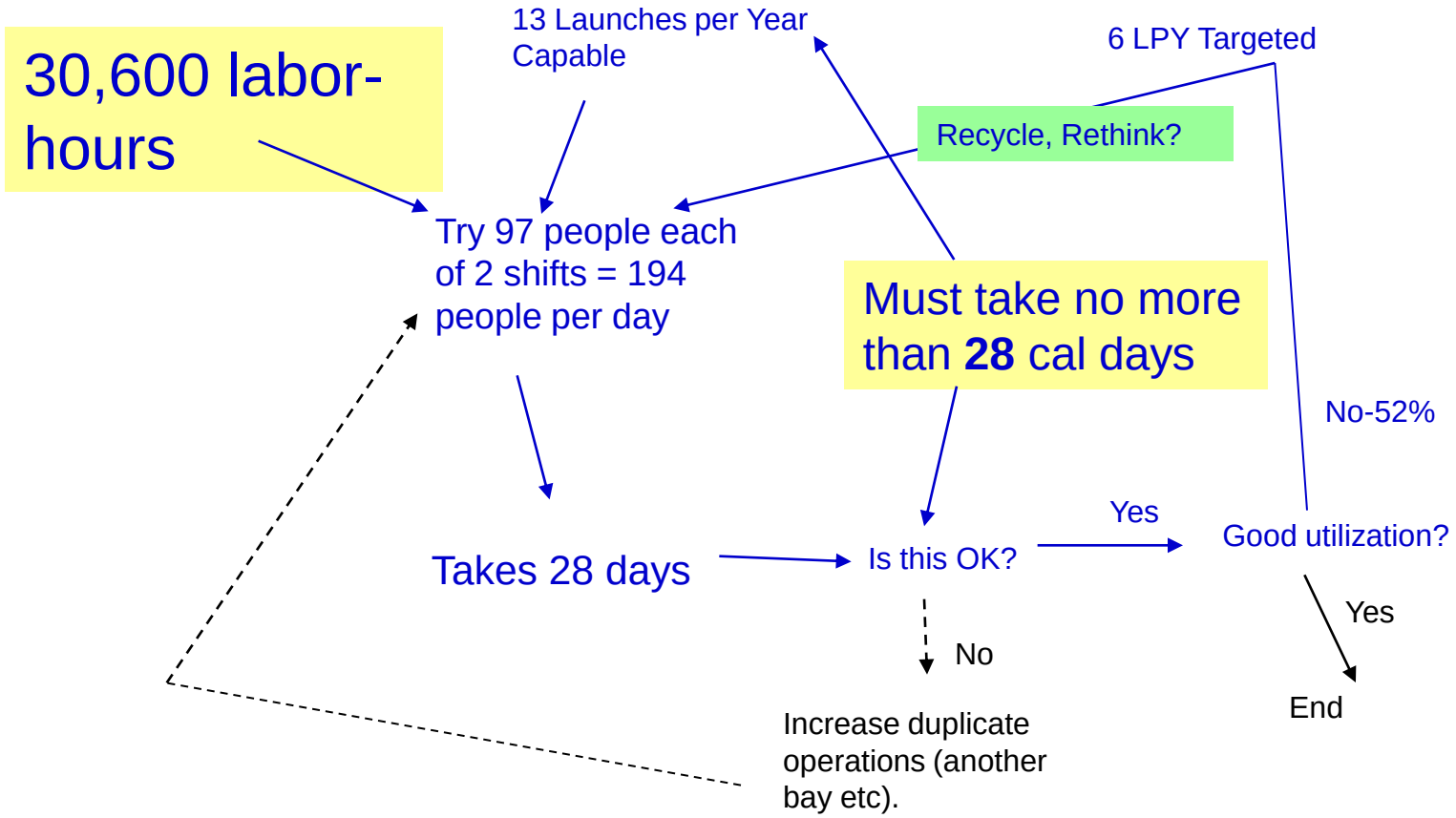
Potential Experiments & Analysis Approach – Families of Curves

- **Example A**
  - 1-Set labor-hours of work content per flow
  - 2-Set launches per year targeted



Potential Experiments & Analysis Approach – Families of Curves

- **Example B**
  - 1-Set labor-hours of work content per flow
  - 2-Set flow time limits



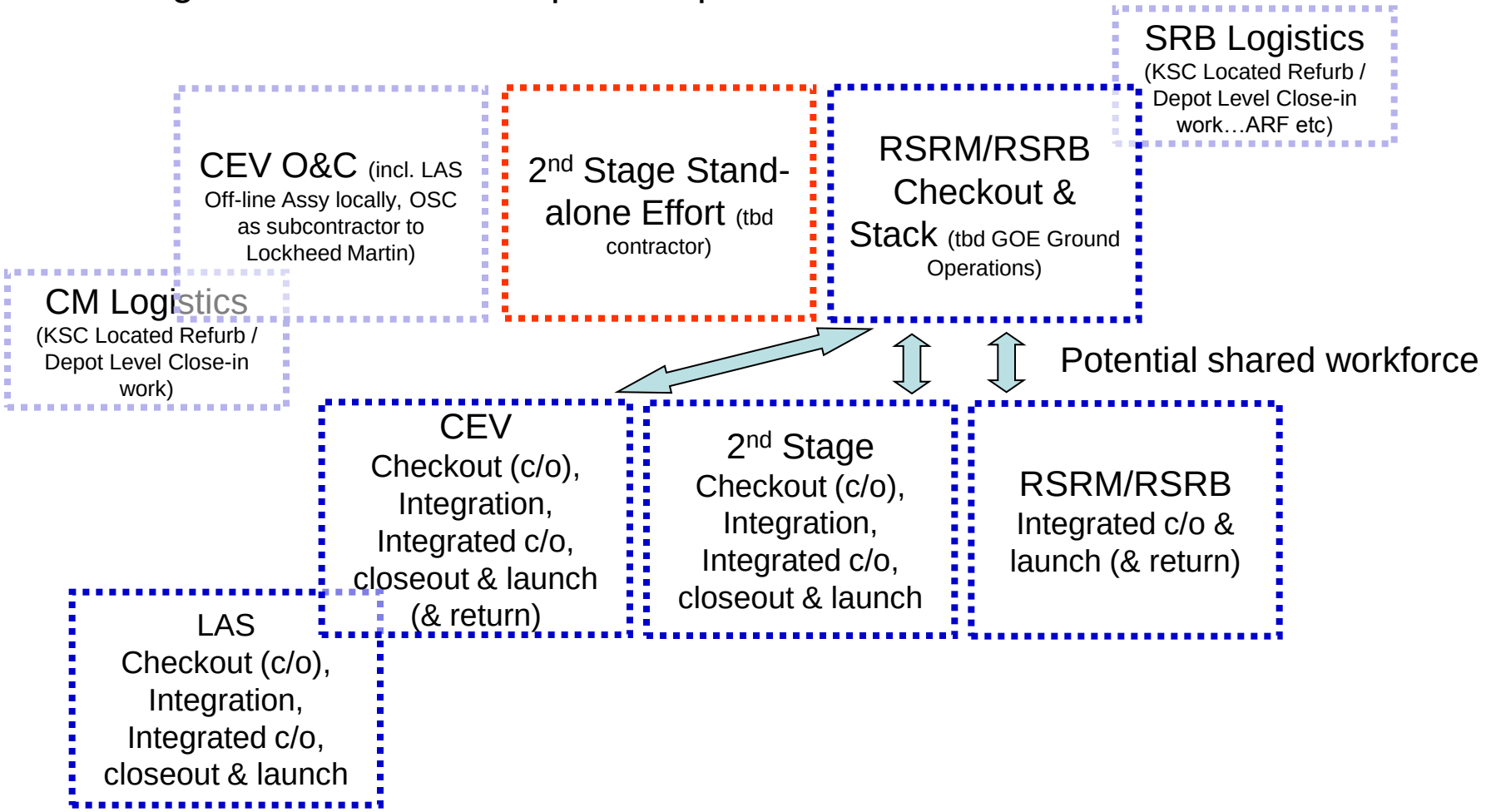
Potential Experiments & Analysis Approach – Families of Curves

♦ Baselines to remember:

- Space Shuttle STS @ ~ 140,000 Ground Operations-type technician labor-hours per flow is apx. 33% or ~ 46,200 labor hours per flow "vertical" or what would be "post DD250" by today's GOE accounting.
  - Value definitely higher pending further analysis; any analysis extrapolating from STS Space Shuttle "means" requires significant review of confidence as repeatability & or margin as a result.
    - Example: If the "mean" data of processing times, data that has been cleaned up to exclude off-nominal flows, were used to extrapolate forward to launches, the STS Space Shuttle Launch rate per Year would be (365 / (81+7+34))*3 vehicles = ~ 9 Launches per Year (*reductio ad absurdum*).
  - Discrepancy in arriving at an actual average is due to the inclusion or not of very off-nominal events such as month long stand-downs or delays, lowering of flight rate without a proportional drop in work-force, and overall fixed cost behaviors.
- Space Shuttle total end-to-end KSC serial "duration hours" are apx. *50,000 cumulative task hours of which apx. ~ **21,000 of the total cumulative task hours per flow are "vertical" or what would be "post DD250" by today's GOE accounting.
  - Roughly coincides with the labor-hours crew-loading data if assume ~ 2 to 3 people per task.

Potential Experiments & Analysis Approach – Families of Curves

- **Sample 1st order Orion Ares I KSC Estimation – Step 1 of 2**
  - Delineate by the roles and responsibilities to date, build, checkout (c/o), integrate, launch, return, pre and post DD250.



Potential Experiments & Analysis Approach – Families of Curves

- **1st order Orion Ares I KSC Estimation – Step 2 of 2**
  - Simplify by behavior of cost